Dorset Council Residential Lifecycle Embodied Carbon and Operational Carbon Analysis

Rev 3

For Dorset Council

REF / 10164
November 2020

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Existing building, North Quay, Weymouth

Contents

Existing office building North Quay, Weymouth

Proposed residential development on North Quay, Weymouth (Image by Ben Pentreath & Associates, provided by Dorset Council)

1. Introduction

1.1 Approach

Dorset Council have commissioned Architype to undertake a review of the lifecycle embodied carbon and operational carbon of two residential schemes submitted for planning on the North Quay site, Weymouth. The two schemes being reviewed are the permitted development application for change of use in the existing building, approved in the summer of 2016, and the new build residential scheme approved in 2015. This report follows similar investigations for the retrofit of the existing office building and a larger residential new build scheme on the same site.

The primary aim of the study is to provide a high level comparison of the environmental impact of a new residential development on the North Quay site, looking at different embodied and operational carbon scenarios. These scenarios are compared against a baseline of the current office building continuing in its current operation - ie. Business as Usual (BAU).

It should be noted that this study represents a high level analysis and outputs are strictly for comparison purposes only. Foundations, landscaping and external works have not been included in the analysis.

The comparison focuses on the following key strategies:

Business as Usual - as an office building. Undertaking no major work to the building and continuing to operate as now. No embodied carbon impact from refurbishment and existing operational carbon impact. This strategy provides a baseline scenario for comparing environmental impacts of the refurbishment and new build options.

Residential Eco-refurbishment - Undertaking a deep refurbishment/retrofit of the building to the Passivhaus 'Enerphit' standard. No embodied impact from superstructure as retained. Embodied impacts from the fabric and services upgrade along with end of life impacts have been considered. Significantly improved operational carbon performance against baseline.

Residential Timber Frame_Passivhaus - Demolishing the existing building and subsequently redeveloping the North Quay site into residential accommodation, using a timber frame structure which leads to significantly lower embodied carbon emissions. This option assumes certification to the Passivhaus Standard which will radically reduce operational energy consumption.

Methodology
The embodied carbon calculations for the above strategies were carried out using ECCOlab. ECCOlab is a web based tool that enables life cycle assessment of new build and refurbishment projects from the early stages of design to completed buildings.

The layouts for the proposed residential refurbishment and the new build development were provided by Dorset Council.

The layouts for the proposed new build development were developed by Ben Pentreath & Associates on behalf of Weymouth & Portland Borough Council (WPBC) in support of an outline planning application for the demolition of the existing Municipal Council Office Buildings on the site.

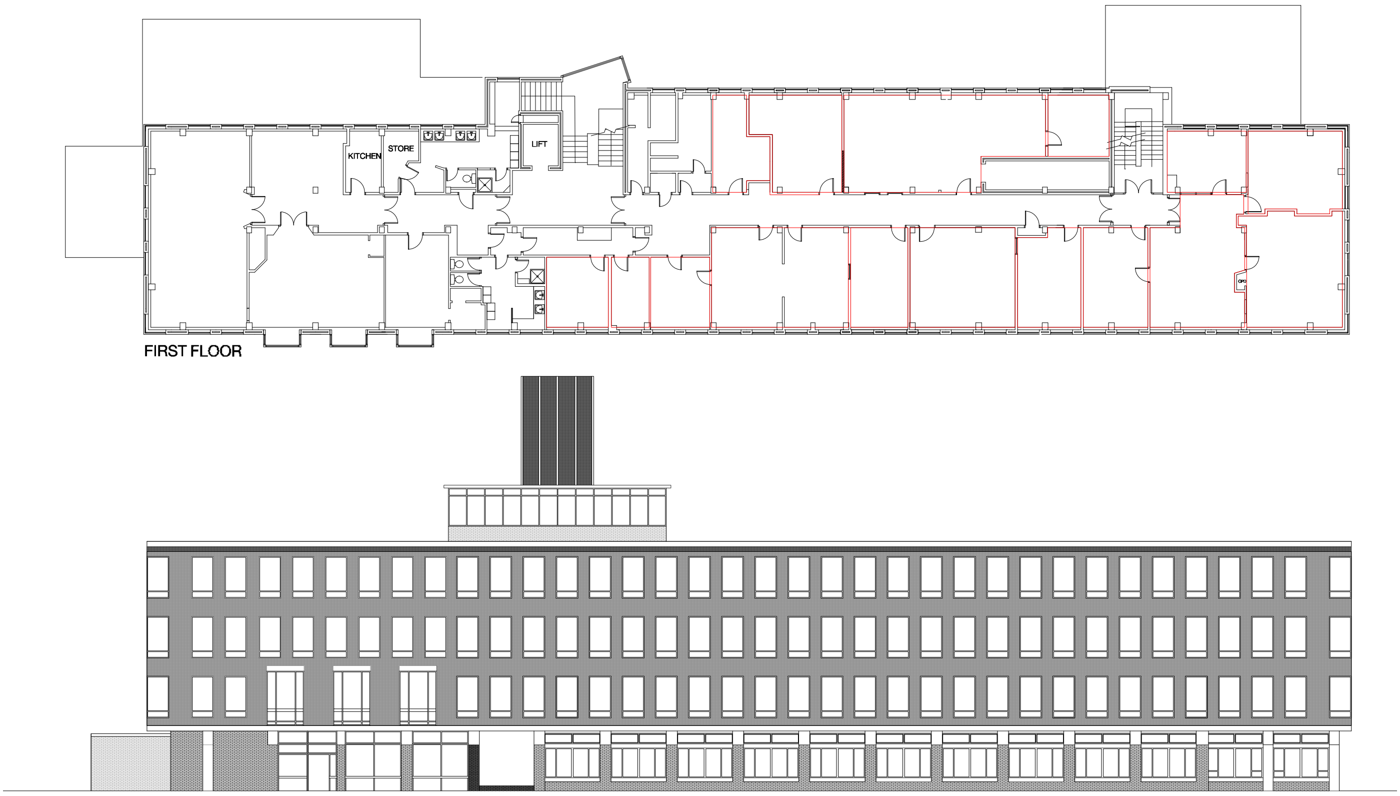


Figure 1.1 CAD plans and elevations of the existing building (provided by Dorset Council)

1. Introduction

1.2 Existing building

The information provided to Architype in November 2019 as part of the previous study was used to create the Business as Usual benchmark for this analysis. The existing office building is located on North Quay, Weymouth, directly overlooking the Marina to the north.

The 4 storey building was believed to be constructed in the 1960's for the purpose of housing the local council's operations. It is understood that no major refurbishment of the building has taken place since this time.

Structure and fabric

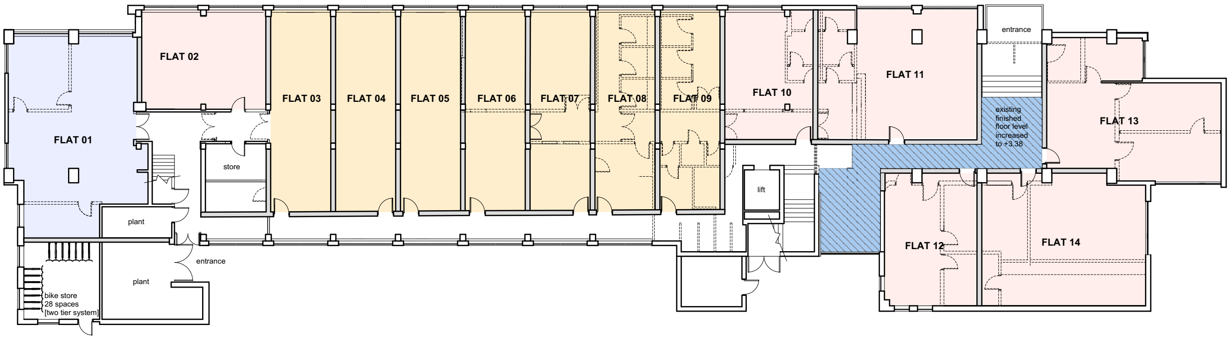
The structure of the building is understood to be a concrete encased steel frame, with concrete roof and floor slabs. The building is clad in Portland Stone. The building appears to be naturally ventilated by the means of opening windows to all façades.

Some CAD drawings and partial historic drawings have been received from the Client - a selection of which is provided opposite. A search of the internet has not produced any further detail on the construction of the existing building.

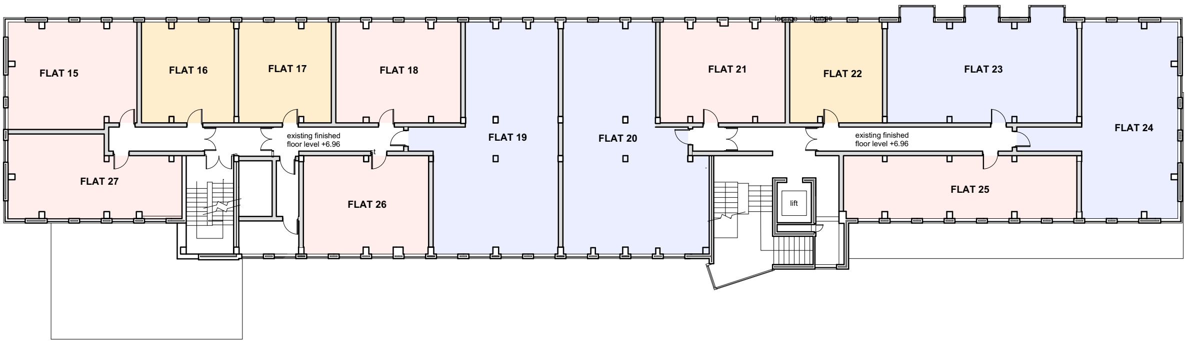
Limit of information

Given the limited information provided to initiate this assessment, certain informed assumptions have had to be made in order to compare options.

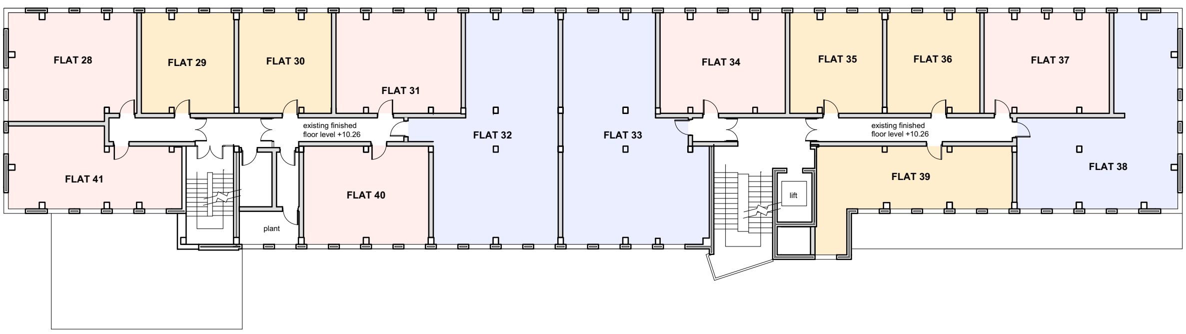
More detailed investigative surveys are recommended to confirm the construction of the existing building should the project progress beyond a feasibility level assessment.



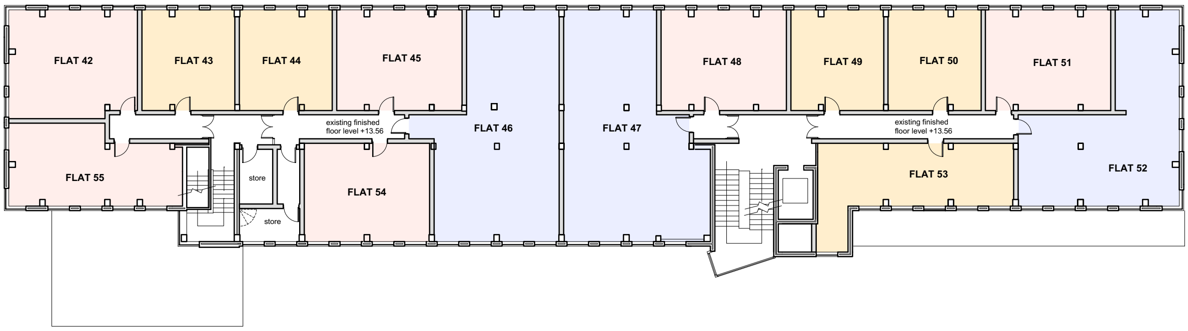
001 | proposed ground floor plan



001 | proposed first floor plan



001 | proposed second floor plan



001 | proposed third floor plan

Figure 1.2 Floor plans for the residential refurbishment (drawings provided by Dorset Council)

1. Introduction

1.3 Existing Building - Residential Eco Refurbishment

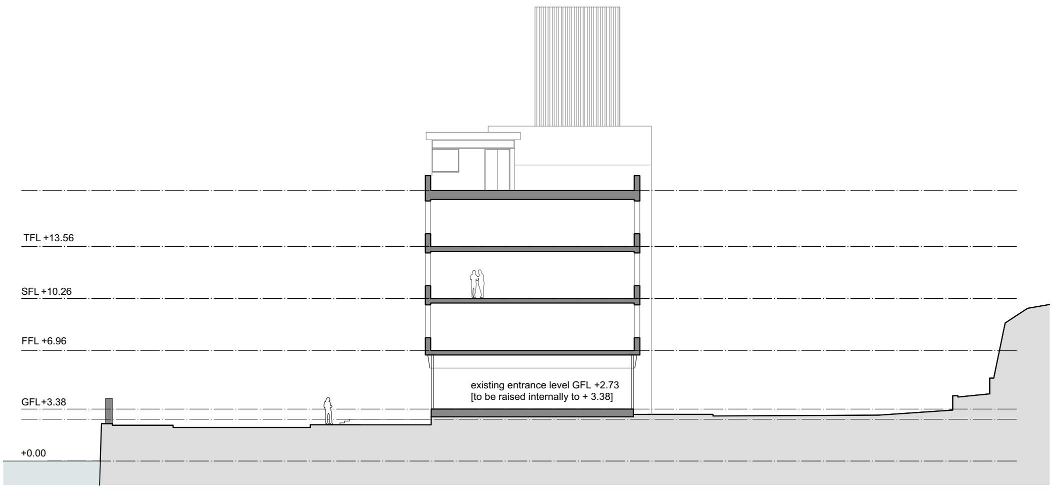
This option involves refurbishing the existing building into residential accommodation to the Passivhaus Enerphit Standard.

The proposed layout was provided by Dorset Council and includes a mix of 1-bed and 2-bed flats. The proposal results in a total of 56 flats.

The structure is retained as is the external cladding. The internal layouts are completely reconfigured while the building's envelope is upgraded to meet the Enerphit standard.

A model of the proposal was created in gModeller, the SketchUp plug-in for ECCOlab and the carbon analysis was subsequently done in ECCOlab.

Regarding operational energy, the Passivhaus Enerphit standard was assumed to be achieved. Passivhaus is considered the most robust standard for significantly reducing a building's energy in use in a cost effective manner. Material assemblies were based on typical assemblies Architype have used before in similar schemes.



001 I proposed section I 1:200 @ A3

Figure 1.3 Section for the residential refurbishment (drawings provided by Dorset Council)

Figure 1.4 Schematic drawings for the redevelopment of the site into a residential scheme (Image by Ben Pentreath & Associates, provided by Dorset Council)

1. Introduction

1.4 New Residential Development

This option involves redeveloping the North Quay site into residential accommodation. It was based on the information provided by Dorset Council that included an Outline Planning Application document from December 2014 produced by Ben Pentreath and Associates, a outline masterplan and elevations showing the redevelopment of the wider site (Figure 1.4). A number of assumptions were made as part of the study including internal layout of flats and construction assemblies. It should be noted that this is a high level analysis and outputs are strictly for comparison purposes only.

The development comprises 72 dwellings and 216m2 of commercial space. The proposal provides a mix of different typologies ranging from flats to townhouses and includes both private and affordable dwellings. The proposal includes a mix of 2, 3 and 4 storey buildings with some pilotis parking and some parking courts. Figure 1.5 shows a breakdown of the proposed accommodation.

A model of the proposal was created in gModeller, the SketchUp plug-in for ECCOlab and the carbon analysis was subsequently done in ECCOlab. Foundations and landscaping have been excluded from these calculations.

Regarding operational energy, the Passivhaus Classic standard was assumed to be achieved. Material assemblies were based on typical assemblies Architype have used before in similar schemes.

NORTH QUAY PROPOSED DEVELOPMENT

Building	no. of dwellings	no. of bedrooms per dwelling	total no. of bedrooms	total no. of bedrooms	total no. of bedrooms	Commercial Area (m2)	
			MARKET	SOCIAL RENTED	INTERMEDIATE		
Town House	7	3	21				
Bldg 1	7	2	14			170	
Bldg 2	1	1	1				
Bldg 2	1	3	3				
Bldg 3	3	2			6		
Bldg 3	3	3	9				
Bldg 3	9	1	9				
Bldg 4	3	1	3				
Bldg 5	3	1	3				
Bldg 5	3	1		3			
Bldg 6	4	2	8				
Bldg 7	6	3		18			
Bldg 7	1	1		1			
Bldg 8	3	3	9				
Bldg 8	4	2	8				
Bldg 9	7	1		7			
Bldg 9	4	2		8			
FOG	2	1	2				
FOG	1	2	2				
TOTAL	72	35	92	37	6		
			68.1	27.4	4.4		%age of total
				86.2	13.8		%age of total affordable housing

TOTAL no. of bedrooms	135

Figure 1.5 Proposed accommodation division (Table by Ben Pentreath & Associates, provided by Dorset Council)

2. Glossary

Abbreviations:

BCIS	-	Building Cost Information Service
CIBSE	-	Chartered Institute of Building Services Engineers
DEC	-	Display Energy Certificate
EPD	-	Environmental Product Declaration
FF&E	-	Furniture, fixtures and equipment
GA drawings	-	General Arrangement drawings
GWP	-	Global Warming Potential
LCC	-	Life Cycle Carbon/ Cost
EoL	-	End of Life
WRAP	-	Waste and Resources Action Programme
GGBS	-	Ground Granulated Blast Furnace Slag
FOG	-	Flats over garage

Terms and definitions:

Embodied carbon:
The resultant emissions from all the activities involved in the creation, maintenance, repair and demolition of a building

Feed-in-Tariff (FIT):
An energy supply policy that promotes deployment of renewable energy resources. It offers a guarantee of payments to renewable energy developers for the electricity they produce.

Operational energy:
Operational energy from the building includes energy consumed for heating, lighting, ventilation, air conditioning and small power. e.g. regulated and unregulated energy.

Operational carbon:
The carbon emissions resulting from the operational energy demand.

Cradle to gate:
A system boundary of an environmental life cycle assessment. A portion of a product life cycle from inception to the point it leaves the manufacturer.

Cradle to site:
A system boundary of an environmental life cycle assessment. A portion of a product life cycle from inception to the point it arrives to the building site.

Cradle to grave:
A system boundary of an environmental life cycle assessment relating to the full life cycle of a product or building including extraction, processing and delivery to site, maintenance, refurbishment, demolition and waste treatment.

ECCOLAB

ECCOlab has been utilised for option appraisal in the low carbon Passivhaus EnerPHit retro-fit of existing office space for the University of Cambridge

Screengrabs of work in progress ECCOlab analysis

3. Methodology

3.1 ECCOlab

The embodied carbon calculations for the case studies were carried out using ECCOlab. ECCOlab is a web based tool that enables life cycle assessment of projects from the early stages of design to completed buildings enabling informed design decision making from the outset of the project throughout the project's development to assessment of the completed building. It was developed by GreenSpaceLive, ChapmanBDSP, Architype and Currie & Brown.

The modelling, analysis and reporting is based on the following recognised industry standards: BS EN 15978:2011 - Sustainability of construction works, BS ISO 15686-5 - Standardised Method of Life Cycle Costing, PAS 2050:2011 and BCIS NRM.

Embodied carbon for Stage A1-3 and C1-4 is assigned directly for each product based on EPD information, manufacturer information and the ICE database. Embodied carbon for Use stage (B1-7) is calculated in ECCOlab according to the predicted service life and maintenance profiles which are defined for each component and component assembly. Service life periods for each product were defined based on EPDs, product data sheets, warranties and general references as Fannie Mae Estimated Useful Life Report. Where EPDs did not include information on End of Life carbon (stage C), it was estimated as 3% of the Product stage (A1-A3) carbon. Materials' density, specific heat capacity and conductivity were based on EPD, material data sheets and CIBSE Guide A.

The carbon emissions for transport to site (Stage A4), are calculated using ECCOlab's dynamic transportation calculation for point-to-point geo-positional transportation. All locations are defined by country, latitude and longitude. Point-to-point distance calculations are used for inland transportation between sites or to shipping ports, modified with appropriate country specific wiggle factors and transport splits. For each landmass origin and destination, the engine establishes the shipping route to be used. Calculated distances are then converted into carbon CO2eq emission factors for road freight, rail and shipping, using the latest recognised figures produced by DECC in the UK. This represents a conservative estimate of total transport impacts, as it assumes the most efficient route possible from manufacture location to site.

Data input & modelling assumptions

The data for the modelling of the existing building was based on the following information supplied by Dorset Council:

- AutoCAD drawings of the existing building - plan and elevation
- Annual energy bills of the existing building
- Internal photos of the existing building
- Very limited construction information (3 details) of the existing building
- The Outline Planning Application (PDHAS) document for Weymouth North Quay, December 2014, prepared by Ben Pentreath & Associates.
- 1 AutoDAD Masterplan and 2 AutoCAD North Elevation drawings of the proposed North Quay Residential Development, prepared by Ben Pentreath & Associates.

Where no project information was provided typical material assemblies were used from ECCOlab's database. The reference study period was defined as 60 years.

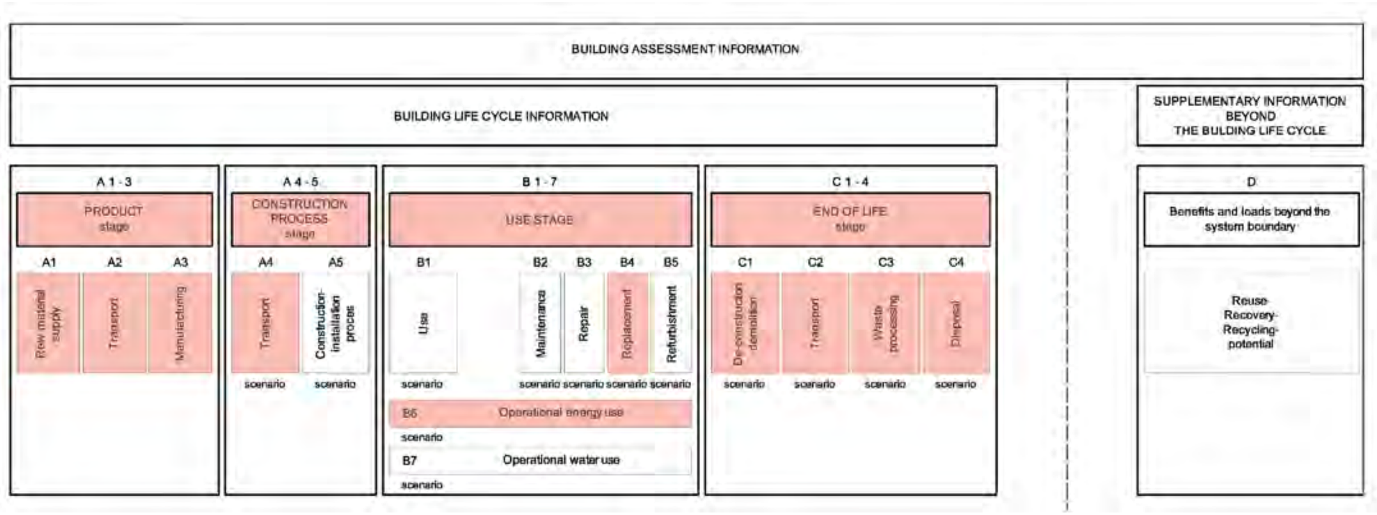


Figure 3.1 Display of modular information for the different stages of the building assessment (Source: BSI 2011)
- Highlighted stages are included in the scope of this report.

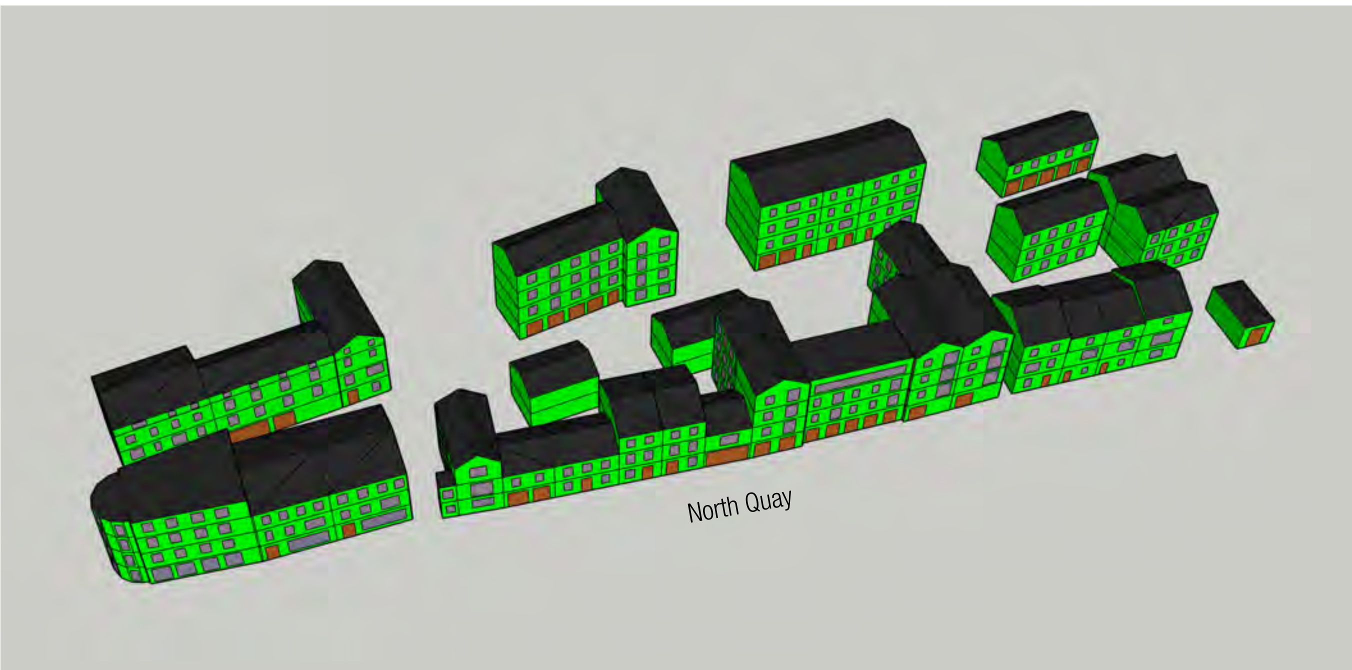


Figure 3.2 ECCOlab model of the proposed residential scheme

3.2 Life cycle carbon analysis

The study analyses the carbon emitted throughout the life of the building (Figure 3.1). The building life cycle includes construction, use and deconstruction commonly termed ‘cradle to grave’. It aligns with the relevant standard BS EN 15978 [2] which splits down the energy associated with construction projects into the following stages:

- Product stage (A1-A3)
- Construction process stage (A4-A5)
- Use stage (B4)
- End of life stage (C1-C4)

Supplementary information beyond the building life cycle (D) is beyond the scope of this analysis. Following EN 15804 approach, any benefits of recycled materials that are currently taking place are included in product stage A1-A3.

Foundations and landscape design have been excluded from these calculations.

3.3 Operational carbon analysis

The operational carbon estimation (Use Stage B6) has been derived for each option on the following basis:

Business as Usual – Annual energy bills for the office’s electricity and gas usage have been provided for the last 6 years by the client. Operational carbon has been derived based on an average of previous performance using typical regional utility costs per unit and current grid carbon factors.

Eco-refurbishment – based on previous analysis by Architype of similar Passivhaus EnerPHit projects.

New Residential _Passivhaus – based on previous analysis by Architype of similar Passivhaus projects

Regulated and un-regulated energy, including the energy consumed for heating, lighting, ventilation and small plug-in power, has been included in the operational carbon figures throughout.

Operational water impact has not been considered in the analysis. In general the carbon impact of mains water supply is low and would not have a bearing on the outcomes of the study.

3.4 Renewable energy and LZC

The comparisons presented in this report focus on embodied carbon, fabric performance and operational energy. Options for renewables and LZC technologies have not been considered.

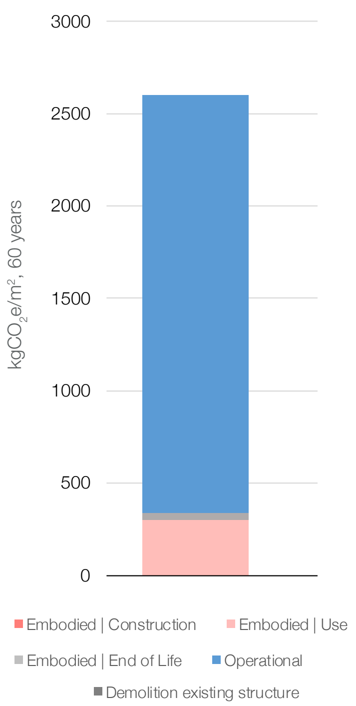
On-site renewable generation, for example building integrated photovoltaics panels, could be added to any of the options with a similar beneficial impact on energy consumption and operational carbon.

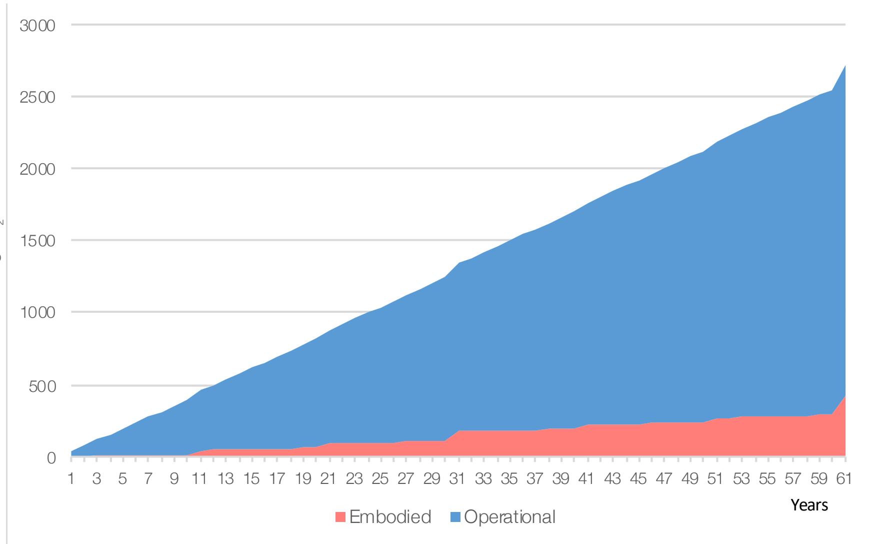
4. Carbon Analysis

4.1 Business as Usual - Office use

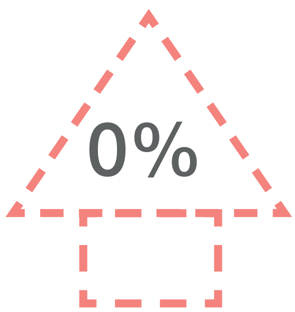
The following analysis investigates the option of leaving the building as it stands and continuing to operate as office space through a further 60 year lifespan. This option creates a theoretical baseline for comparison of further options. The following strategic decisions have been made in the analysis:

Structure	Above and below ground	Retained - steel columns encased in concrete, 200mm concrete floor slabs, 300mm ground floor slab
Building Fabric	External walls and roofing	Retained - cavity construction, masonry and portland stone, limited insulation. Existing roof system left in place
	Windows and doors	Retained - single glazed opening units.
	Internal walls and partitions	Retained - masonry partitions
	Internal finishes	Retained - Suspended ceilings, carpets
Operational Energy	Figures taken from energy bills provided by the Client	
Assumed building lifespan	60 years	





Lifecycle Carbon Impacts	60 years	Business as Usual	Concrete _Build
Embodied Carbon Impact *kgCO2e/m2/yr*	Demolition of existing structure	0	
	Total A - Construction	0	
	Total B - Use 60 years	305	
	Total C - End of Life	33	
	Total Embodied, 60 years	**338**	
Operational Carbon Impact kgCO2e/m2/yr	Operational per year	38	
	Total Operational, 60 years	**2260**	
Total Lifecycle Carbon Impact *kgCO2e/m2/60yrs*		**2598**	

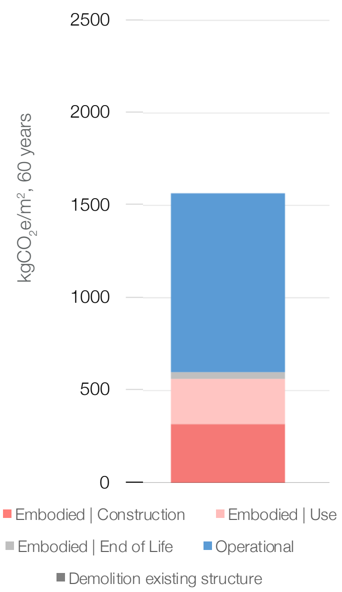


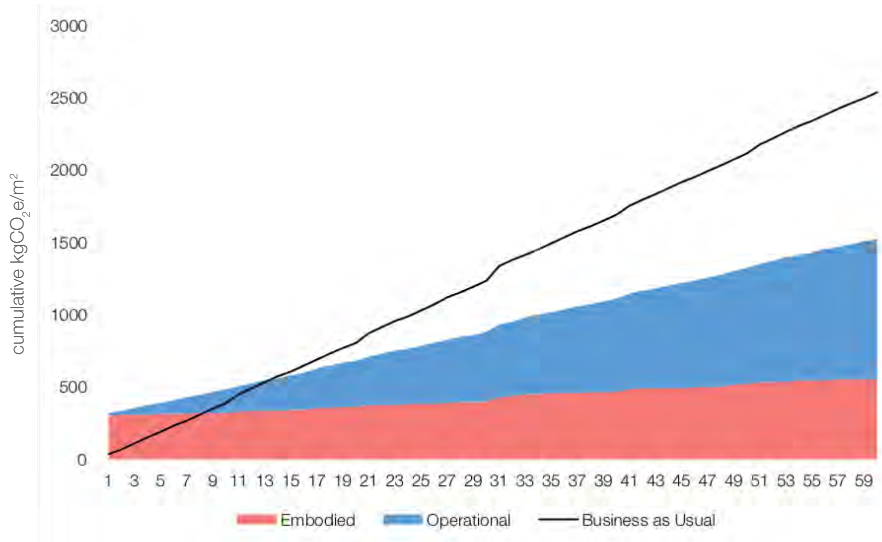
Percentage Improvement

4.2 Residential Eco-Refurbishment

The following analysis investigates the option of undertaking a deep refurbishment to the Passivhaus Enerphit Standard and converting the existing building into residential accommodation. This option establishes minimum operational carbon impacts and also analyses the impact of using low embodied carbon materials and systems in the refurbishment. The proposed layout was provided by Dorset Council and includes a mix of 1-bed and 2-bed flats. The proposal results in a total of 56 flats. The following strategic decisions have been made in the analysis:

Structure	Above and below ground	Retained - steel columns encased in concrete, 200mm concrete floor slabs, 300mm ground floor slab
Building Fabric	External walls and roofing	Existing external wall system retained. Internal insulation system on metal frame with plasterboard lining introduced. Existing roof system removed and replaced with insulated warm roof system. U-values to Passivhaus Enerphit standard
	Windows and doors	Existing units removed and replaced with high performance triple glazed opening units to Passivhaus Enerphit standard
	Internal walls and partitions	Existing internal walls removed and replaced with metal stud, acoustic insulation and plasterboard system
	Internal finishes	Existing finishes removed and replaced with new plasterboard ceiling, linoleum floors and paints
Operational Energy	Figures taken from Passivhaus Enerphit standard	





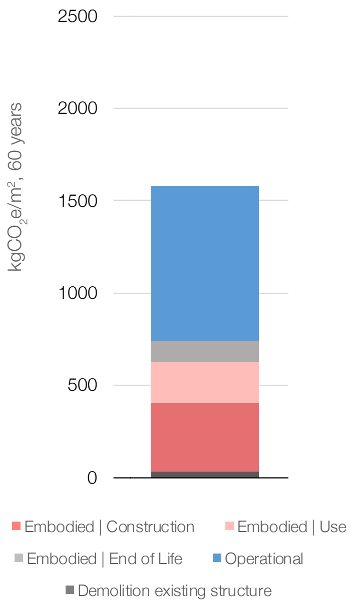
Lifecycle Carbon Impacts kg per m2	60 years	Refurbishment Eco
Embodied Carbon Impact *kgCO2e/m2/yr*	Demolition of existing structure	0
	Total A - Construction	318
	Total B - Use 60 years	244
	Total C - End of Life	36
	Total Embodied, 60 years	**598**
Operational Carbon Impact *kgCO2e/m2/yr*	Operational per year	16
	Total Operational, 60 years	**966**
Total Lifecycle Carbon Impact *kgCO2e/m2/60yrs*		**1564**

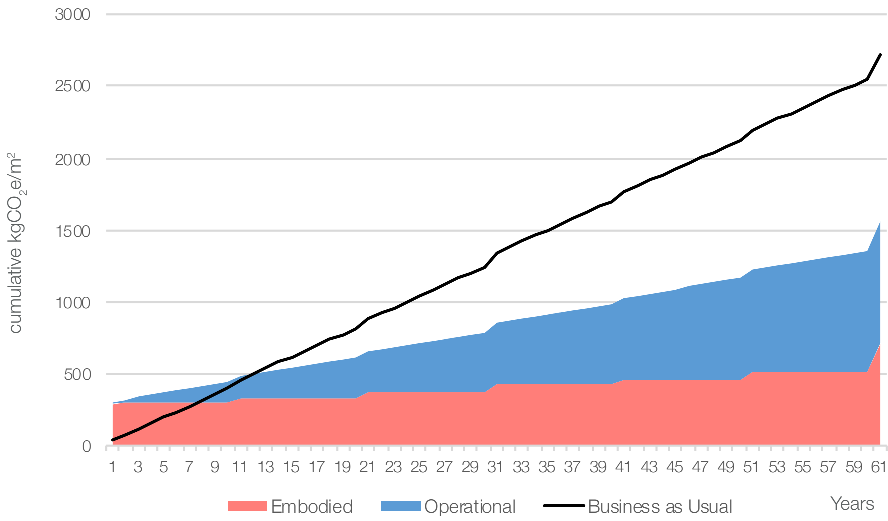
Percentage Improvement

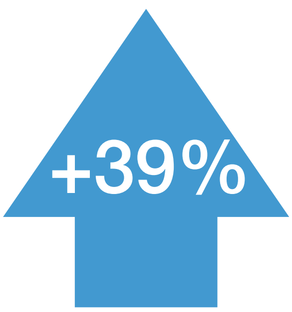
4.3 Eco Development - Residential Timber Frame_Passivhaus

The following analysis investigates the option of redeveloping the North Quay site into residential accommodation, using a timber frame structure. This option assumes certification to the Passivhaus Standard which will radically reduce operational energy consumption. The following strategic decisions have been made in the analysis:

Structure	Above and below ground	Timber frame with timber floor slabs. Concrete ground floor slab.
Building Fabric	External walls and roofing	New external walls - brick and/or stone cladding and timber frame system with plasterboard internal linings. Tiled roof on timber structure with mineral wool insulation. U-values to Passivhaus standard
	Windows and doors	New high performance triple glazed opening units to Passivhaus standard
	Internal walls and partitions	New metal stud, acoustic insulation and plasterboard system
	Internal finishes	New plasterboard ceiling, carpet floors and paints
Operational Energy	Figures taken from Passivhaus standard	
Assumed building lifespan	60 years	







Percentage Improvement

Lifecycle Carbon Impacts	60 years	**Timber Frame_PH**
Embodied Carbon Impact *kgCO2e/m2/yr*	Demolition of existing structure	33
	Total A - Construction	374
	Total B - Use 60 years	217
	Total C - End of Life	115
	Total Embodied, 60 years	**739**
Operational Carbon Impact *kgCO2e/m2/yr*	Operational per year	14
	Total Operational, 60 years	**840**
Total Lifecycle Carbon Impact *kgCO2e/m2/60yrs*		**1579**

5. Comparison and Conclusions

5.1 Comparisons and Conclusions

The section visually compares the relative lifecycle carbon impact of the different scenarios analysed in the report through a series of charts and tables.

Taking the results of each scenario in turn:

Business as Usual – This option has no initial carbon impact as the building is left as is. It does however have a very significant carbon impact over the 60 year lifecycle due its relatively poor operational energy performance.

Residential Eco-Refurbishment – This option incurs a small initial embodied carbon impact from the refurbishment works which results in a significant improvement in operational energy performance. The carbon penalty of the initial works is paid back in approximately 13 years. This option has the best overall carbon lifecycle profile as it benefits from the retention of the existing building structure and also delivers very low carbon in use.

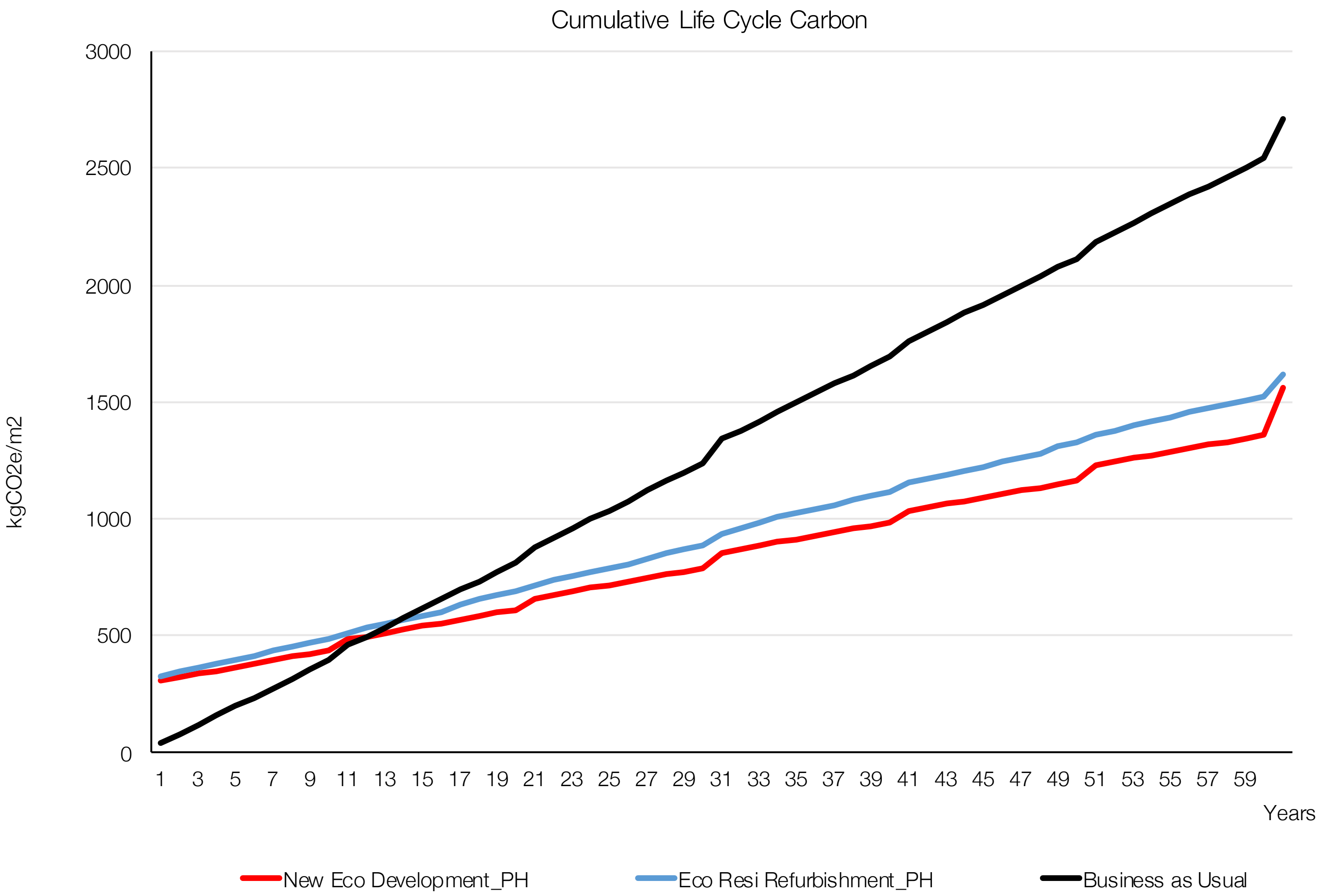
New Eco Development - Residential Timber Frame_Passivhaus- This option incurs an initial embodied carbon impact from replacing the existing building structure. However, the proposed timber frame for the new buildings has a relatively low carbon impact compared to other frame options and represents the best structural option for the development from an embodied carbon perspective. The Passivhaus standard building envelope results in a significant improvement in operational energy performance over business as usual. Passivhaus is also considered an industry leading standard for low energy design and is also recognised for delivering expected energy savings due to a rigorous QA process during construction. The carbon penalty of the initial works is paid back in approximately 13 years. However, there is an impact at end of life resulting from the release of sequestered carbon in the timber structure.

In summary, both the 'Eco Refurbishment' and the 'New Eco Development - timber frame Passivhaus' options are significant improvements over the existing building's operation and begin to show a lifecycle carbon payback after approximately 13 years. However, when comparing cumulative lifecycle carbon, (kgC02e/m2), there is only a minor difference in figures between the two development options on a per m2 basis.

Therefore, for the purposes of comparison and given the relatively basic level of information that was provided about the schemes' construction, this report cannot provide clear evidence that either the 'Eco Refurbishment' or the 'New Eco Development - timber frame Passivhaus' is better from a lifecyle carbon perspective on a per m2 basis.

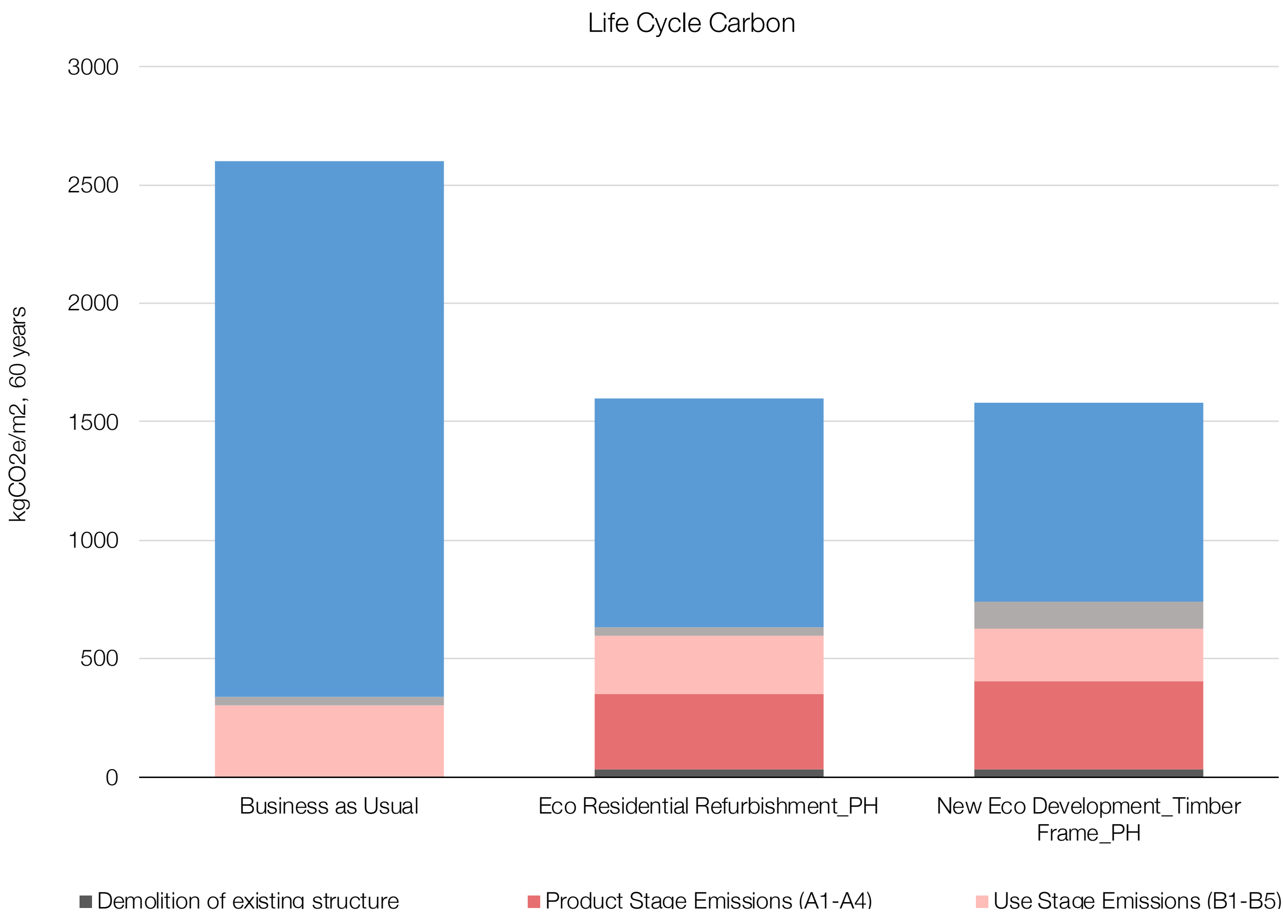
If however, you need to build more and larger units than refurbishment of the existing building can provide, this report and its previous iterations, is good evidence that taking a Passivhaus + low embodied carbon approach has significantly improved lifecycle carbon outcomes than the other construction and operational energy standards reviewed.

5.2 Cumulative lifecycle carbon*, kgC0$_2$e/m2



* The impact of demolition of existing office building is not captured in this graph

5.3 Lifecycle carbon comparison, $kgC0_2e/m^2$ 60 years by lifecycle stage



5. Comparison and Conclusions

5.4 Lifecycle carbon impact comparison, kg per m^2

Lifecycle Carbon Impacts	60 years	Business as Usual	Eco Residential Refurbishment_PH	New Eco Development_Timber Frame_PH
Embodied Carbon Impact *kgCO2e/m2/yr*	Demolition of existing structure	0	33	33
	Total A - Construction	0	318	374
	Total B - Use 60 years	305	244	217
	Total C - End of Life	33	36	115
	Total Embodied, 60 years	**338**	**598**	**739**
Operational Carbon Impact kgCO2e/m2/yr	Operational per year	38	16	14
	Total Operational, 60 years	**2260**	**966**	**840**
Total Lifecycle Carbon Impact *kgCO2e/m2/60yrs*		**2598**	**1564**	**1579**

5.5 Lifecycle carbon impact comparison, tonnes whole building

Lifecycle Carbon Impacts Total tonnes whole building	60 years	Business as Usual	Eco Residential Refurbishment_PH	New Eco Development_Timber Frame_PH
Embodied Carbon Impact *tnCO2e/yr*	Demolition of existing structure	0	122	307
	Total A - Construction	0	1180	3484
	Total B - Use 60 years	1131	903	2024
	Total C - End of Life	122	133	1069
	Total Embodied, 60 years	**1253**	**5573**	**6884**
Operational Carbon Impact *tCO2e/yr*	Operational per year	139	60	130
	Total Operational, 60 years	**8370**	**3578**	**7824**
Total Lifecycle Carbon Impact *tCO2e/60yrs*		**9623**	**5794**	**14708**

5. Comparison and Conclusions

5.6 Proportional total lifecycle carbon impact, tonnes $C0_2e$ 60 years

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